AS Unit 1: Basic Biochemistry and Cell Organisation

Name:	Date:

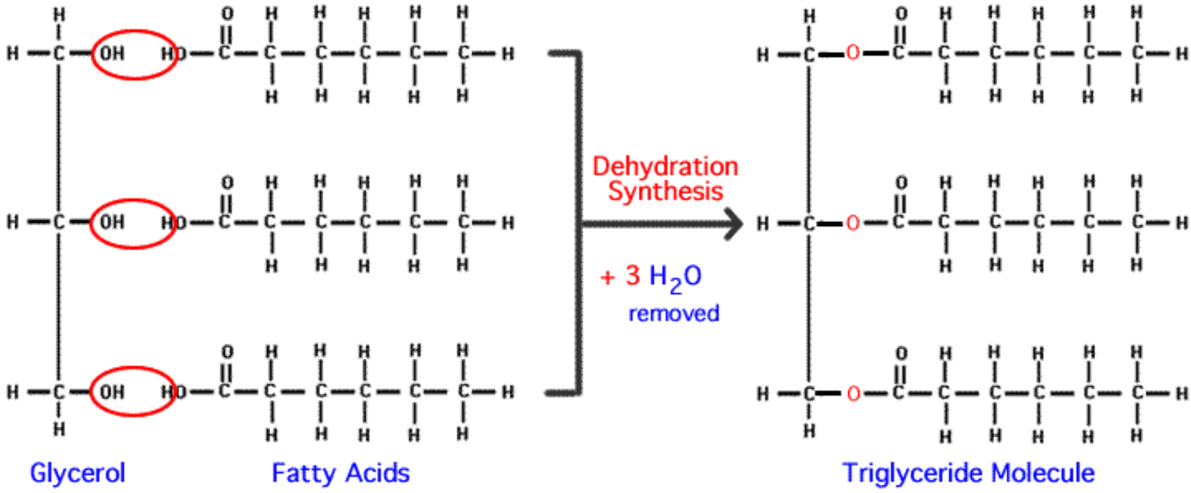
<u>Topic 1.1 Biological Compounds, Lipids</u> – Page 4

I. <u>Lipids</u>

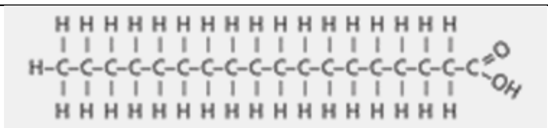
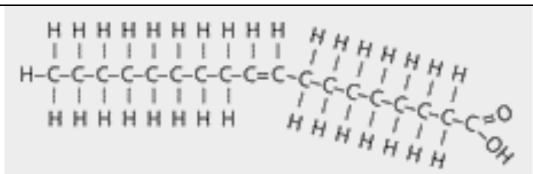
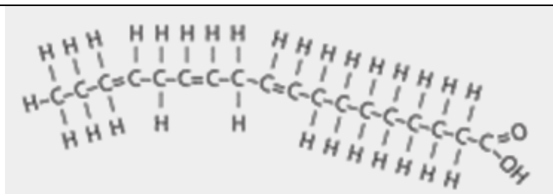
		Completed
1.	Go through the PPT on Lipids	
2.	Read the following handouts: • 1.1L Intro to Lipids • 1.1M Structure and Function of Lipids • 1.1N More Lipid Notes • Rowlands p14-15 • Toole p20	
3.	Complete the questions on H/O 1.1O Lipids	
4.	Homework: Be able to draw and talk about the structure of the following: • Glycerol Molecule • Saturated fatty acid • Unsaturated fatty acid • Condensation and formation of a triglyceride • Label an ester bond/link	

Introduction to Lipids

Lipids.
Lipids are a large group of organic molecules that are all insoluble in water. One of the principle groups is the **triglycerides**. Triglycerides are formed from the condensation reaction of three fatty acids with a molecule of glycerol. The bond formed is called an **ester bond.**



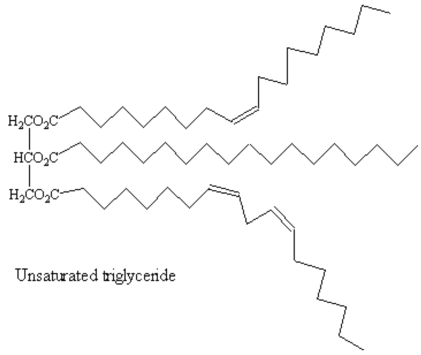
The fatty acids that are combined with the glycerol can be of three different forms as in the table below.

Type	Structure
Saturated (no double bonds)	
Monounsaturated (one double bond)	
Polyunsaturated (>one double bond)	

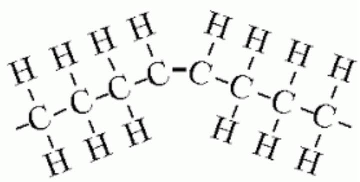
The difference in these fatty acids is whether or not there is an abundance of hydrogen atoms bonded to the carbons. If the carbons have two hydrogen each, then it is called a saturated fatty acid. If there is one less hydrogen, then a double bond will form (i.e. where the missing hydrogen is) and a monounsaturated fatty acid will form. If there is even less hydrogen present, then a polyunsaturated fatty acid forms with multiple double bonds. The double bonds usually give the molecule a kink or bend.

Triglycerides do not need to have three identical fatty acids attached to the glycerol. The diagram below shows an unsaturated triglyceride with three different fatty acids. This type of skeletal drawing saves time by not drawing all of the separate carbon, hydrogen and oxygen atoms.

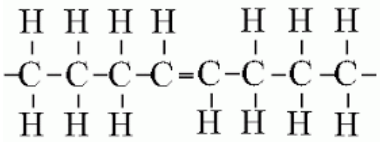
If fatty acids have double bonds then at the double bond, the hydrogen can be on the same side (cis isomer) or across the bond (trans isomer).



Unsaturated triglyceride



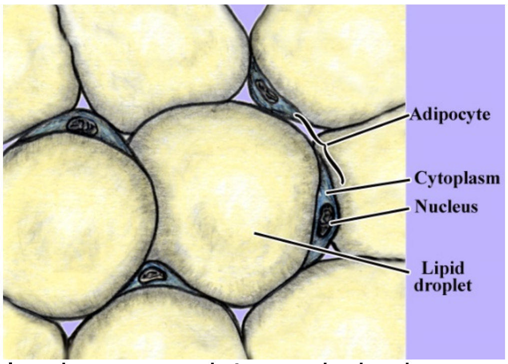
Cis configuration - bent molecule



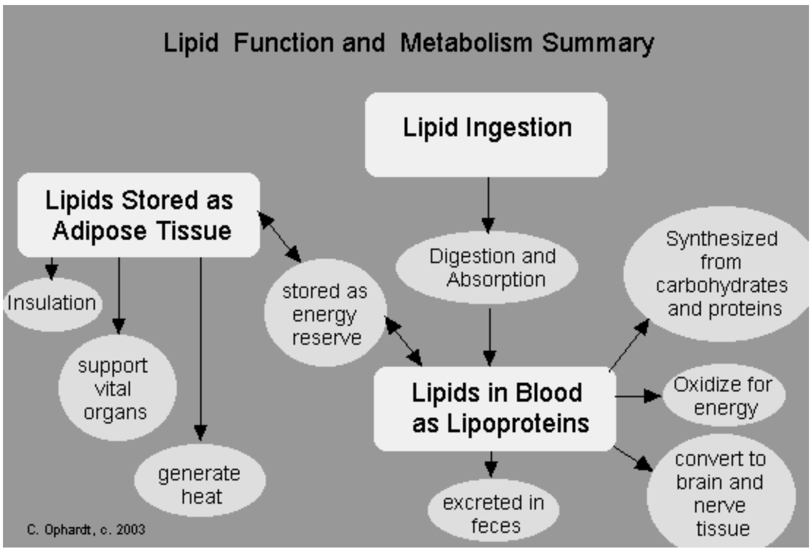
Trans configuration - straight molecule

Lipids and Energy Storage

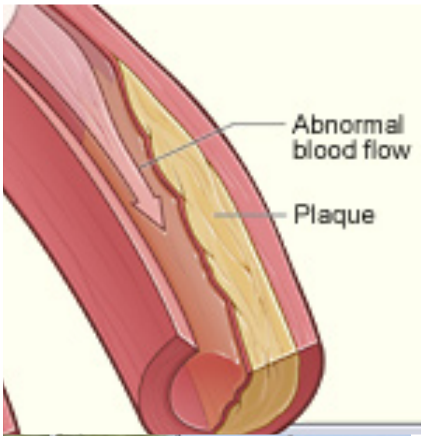
Both carbohydrates and lipids are used as energy stores in organisms. However, lipids are usually preferred for long-term energy storage. In animals the lipids are fats stored in adipose tissue under the skin and around organs.
The advantages of storing lipids rather than carbohydrates include:



- ✓ The amount of energy stored in lipids is about double that stored in carbohydrates (gram for gram)
- ✓ The mass of lipids needed to produce the same amount of energy is therefore halved. This is important especially for flying organism.
- ✓ Stored lipids can provide secondary roles, such as thermal insulation and the shock absorbing protection around organs.
- ✓ For short-term needs, carbohydrates such as glycogen can be broken down much more readily to produce glucose molecules, making them a faster energy provider.



Scientific Evidence for Health Risks Associated with Trans and Saturated Fats



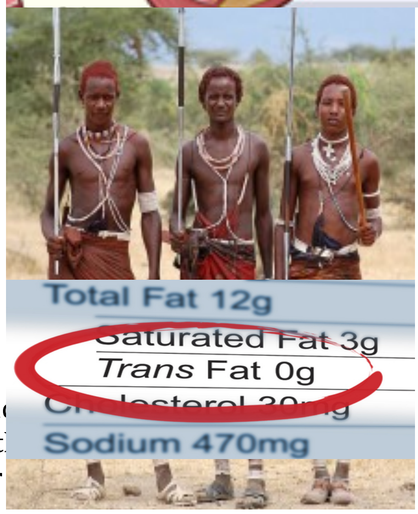
There have been many claims about the risks associated with eating different types of fats. The biggest concerns are about coronary heart disease (CHD). This is a condition that is marked by fatty deposits being found in the coronary arteries that increase the chances of having a heart attack.

A positive correlation has been found between saturated fatty acids and CHD, and these are considered the 'bad' fats. However, a correlation does not mean that saturated fatty acids cause CHD. There could be another factor at play. Perhaps those people surveyed also had poor diets in general.

A population who do not fit the pattern are the Maasai of Kenya. These people consume a diet rich in meat, fat, blood and milk (all high in saturated fats) but have an extremely low occurrence of CHD.

Mediterranean meals are famous for the large level of olive oil consumed. Olive oil contains cis-monounsaturated fatty acids. Unsaturated fats have been branded as 'good' fats. The level of CHD in those areas is extremely small. Again, other factors could come into play; genetics, popular use of garlic, over-use of tomatoes etc.

The positive correlation between trans-fats (almost all of these are man-made by hydrogenating unsaturated fats to extend the shelf life) and CHD has been tested extensively, and would seem to be a cause of CHD. Patients who died from CHD all had high percentages of trans-fats in the walls of their arteries.



Scientists must be very careful when making conclusions with their data. Evi
from looking at scientific research. There are always questions to ask about t
1) How well do the results support the health claim? Strongly, moderately or
Ask:

- ✓ Is there a correlation between intake of lipids and the rate of disease or health benefit?
- ✓ How large is the mean difference between rates of the disease and levels of lipid intake?
- ✓ How widely spread is the data around the mean (this is called the standard deviation)?
- ✓ If statistical tests have been used, do they show a significant difference?

2) Were the methodologies used rigorous? Are there uncertainties at play?
Ask:

- ✓ How large were the sample groups?
- ✓ How controlled were the groups in terms of sex, mass, age, life style etc.?
- ✓ Were there any adjustments made to the data to eliminate other factors?
- ✓ Were the measurements of lipid intake and disease or benefit reliable?

Bio Factsheet

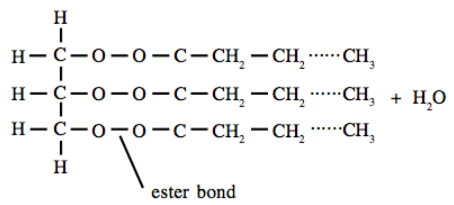
Number 42

The Structure and Function of Lipids

This Factsheet summarises the structure and function of lipids. Lipids are organic compounds found in every type of plant and animal cell. They always contain the elements carbon, hydrogen and oxygen, but the reletive amount of oxygen is less than in carbohydrates.

All lipids are **polymers** – long chains of repeating units joined together in a **condensation** reaction during which water is released. The commonest lipids are triglycerides – three fatty acids and glycerol linked by an **ester bond** (Fig 1).

Fig 1. Structure of a triglyceride



The three fatty acids may be identical but a mixture of fatty acids is also possible. Thus, many different triglyceride structures occur and this in turn means that they have a range of functions. Saturated fats are those which contain single bonds between the carbons in the hydrocarbon chain of fatty acids and these are usually solids at room temperature. Unsaturated fats, e.g. vegetable oils, are liquid at room temperature and have some/many double bonds between the carbons.

Functions

There are eight major functions of lipids.

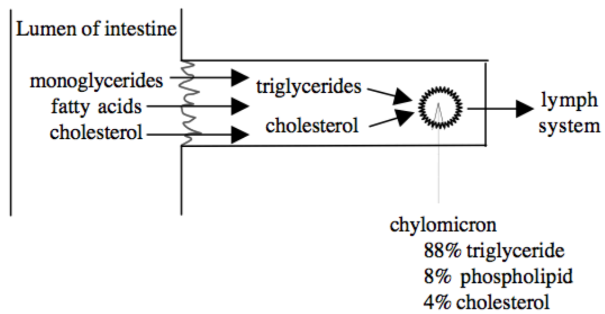
1. **Energy storage**
   Lipids form excellent energy storage molecules, e.g. as lipid deposits in the stroma of the chloroplast and as fats in seeds and adipose tissue of vertebrates. Oxidation of fats to release energy occurs in the mitochondria. As in the oxidation of glucose, acetylcoenzyme A is produced in the first stage, but so are many molecules of NAD and FAD. These are reoxidised in the electron transport chain and hence oxidation of fat yields more ATP than oxidation of carbohydrates. Weight for weight, they are therefore high-energy molecules, which is important in fruits or seeds that need to be dispersed.
2. **Structural components**
   Phospholipids usually make up 40% of cell membranes where their **amphipathic** nature (having a polar and a non-polar end) enable them to contribute to the spontaneous formation of the bilayer. Cholesterol is also a major component of animal cell membranes.
3. **Thermal insulation**
   Fat conducts heat slowly and therefore the triglycerides, which are stored as subcutaneous fat in vertebrates, are important for maintaining optimum temperature for metabolism.
4. **Mechanical protection**
   e.g. of delicate organs, such as kidneys.
5. **Electrical insulation**
   e.g. Sphingomyelin is a specialised phospholipid in the myelin sheet of nerve axons.
6. **Waterproofing**
   e.g. The waxy cuticle on the leaf epidermis or as oils on birds' feathers. The presence of waxy suberin in the Casparian strip of endodermal cells in plant roots forces water into the symplast pathway which is under the control of the nucleus. This strip therefore gives the plant control over substances entering the xylem.
7. **Buoyancy**
   Since fat is less dense than water, fat reserves provide buoyancy for aquatic animals.
8. **Precursors of many cell constituents**
   E.g. gibberellins – plant growth substances e.g. carotenes, photosynthetic pigments, coloration pigments, steroid hormones e.g. testosterone.

How do animals obtain lipids?

Since all cells contain lipids, any animal that eats a plant or animal cell will take in some lipid. Triglycerides and phospholipids are hydrolysed by lipase into glycerol and fatty acids. Since lipids do not dissolve in water, they are not easy to digest and their digestion is accelerated in vertebrates by the secretion of bile salts, which emulsify them into smaller particles, greatly increasing the surface area on which lipase can act.

Fats are hydrolysed by **pancreatic lipases** into fatty acids, monoglycerides and cholesterol. Single triglycerides, phospholipids and cholesterol then diffuse across the brush border of gut epithelial cells (Fig 2).

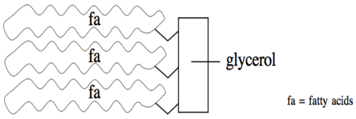
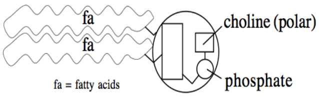
Fig 2. Uptake of lipids in ileum



Once inside the cell, triglycerides are reassembled to form **chylomicrons**. These, plus cholesterol and phospholipids move from the epithelial cells into the lymphatic system. The reassembly of triglycerides in the epithelial cells keeps the concentration of fatty acids low. This maintains the diffusion gradient between the ileum and the inside of the epithelial cells. Lipids are transported in the lymphatic system before entering the bloodstream near the heart.

Typical Exam Question
Describe the structure to function of epithelial cells of ileum.
Microvilli on luminal surface increase surface area for absorption.
Plasma membrane of epithelial cell has protein carriers for active transport.
Epithelial cells contain smooth endoplasmic reticulum for reassembly of triglycerides.

Table 1. Structure, properties and functions of Lipids

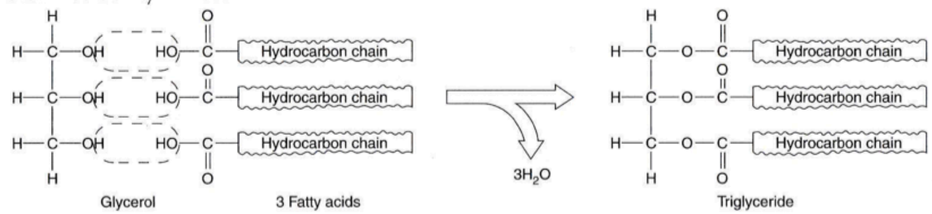
	Structure	Properties	Function
Fatty acids (Fig 1)	Composed of C, H and O and have a carboxyl – COOH group at one end. Saturated fatty acid e.g. Lauric acid $CH_3(CH_2)_{10}COOH$ Monounsaturated fatty acid e.g. Hexadecanoic acid $CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$	May be saturated (no double bonds), monounsaturated (contain a single double bond), polyunsaturated (contain multiple double bonds). Animal fats are mainly saturated and solid at room temperature. Unsaturated fats tend to be liquid.	Energy source in most cells. Saturated fats contain more energy than unsaturated fats because more H, therefore more to reduce NAD/FAD during respiration. Precursors of all other lipids. Energy reserve, e.g. in seeds
Triglycerides (Fig 2)	Glycerol + three fatty acids joined by an ester bond. (May be three of the same fatty acids or may be different.) Contain many C-H bonds  	Determined by nature of fatty acids. Animal triglycerides tend to have (i) larger fatty acids (ii) more saturated fatty acids than plant lipids. Hydrolysis of triglycerides yields metabolic water.	Form in which fatty acids are transported around the body and stored (in adipose tissue) Vital in, for example, desert animals, e.g. camel
Phospholipids	Similar to triglycerides but one fatty acid is replaced with a molecule of phosphoric acid.  	Phosphate-choline 'head' of molecule is polar and hydrophilic. It therefore orientates itself towards any aqueous medium. The fatty acid 'tails' are non-polar and hydrophobic and therefore orientate themselves away from any aqueous layer.	Phospholipids form spontaneous bilayer and are therefore essential components of cell and organelle membranes. Phospholipids are also components of lung surfactants.
Steroids	Cholesterol forms the basis of all steroids e.g. oestrogen/testosterone.	Has a hydrophilic (polar) component and a hydrophobic (non-polar) part and therefore contributes to the membrane bilayer.	Cholesterol is only found in animals where it is a component of and provides fluidity to the cell membranes and is a precursor of bile salts and sex hormones (e.g. oestrogen).
Glycolipids	Combination of carbohydrate and lipid	Carbohydrate portion provides cell 'signature' allowing recognition.	Form hydrogen bonds with water molecules outside the cell membrane, thus stabilising the membrane. Carbohydrate portion may be 'recognised' by antibodies, hormones, etc.
Lipoproteins	Combination of lipid and protein. Large, water-soluble molecules	Polarity confers solubility.	Transport lipids in the blood. Low density lipoproteins (LDLs) transport cholesterol from cells into the blood. High-density lipoproteins (HDLs) remove cholesterol from the blood.
General	Non polar, compact	Insoluble in water Less dense than water Conduct heat poorly	No osmotic effect/cannot diffuse away therefore excellent storage molecule. Excellent waterproofing, e.g. waxy cuticle on plant leaf epidermis and in insect exoskeleton. Provide buoyancy. Subcutaneous fat provides insulation – important for endotherms.

Acknowledgements; *This Factsheet was researched and written by Kevin Byrne*

Lipid structure and function

1.1N Lipids

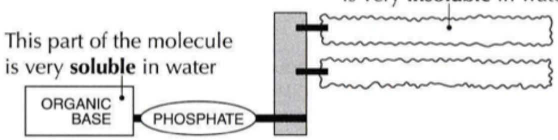
True lipids are esters of fatty acids and alcohols, formed by condensation reactions. Many of their properties result from their insolubility in water.



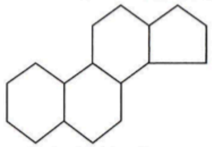
Since the hydrocarbon chains are long (19 C in arachidonic acid) most of the weight of the triglyceride is fatty acid.

Water-repellent properties: oily secretions of the sebaceous glands help to waterproof the fur and skin. The preen gland of birds produces a secretion which performs a similar function on the feathers.

Cell membranes: phospholipids (phosphatides) are found in all cell membranes. These molecules have a polar 'phosphate-base' group substituted for one of the fatty acids in a triglyceride.



Electrical insulation: myelin is secreted by Schwann cells and insulates some neurones in such a way that impulse transmission is made much more rapid.


Basic steroid nucleus

Hormones: an important group of hormones, including cortisone, testosterone and oestrogen, are **steroids**. Steroids are not true esters but have the same solubility properties as them.

Physical protection: the shock-absorbing ability of subcutaneous fat stores protects delicate organs such as the kidneys from mechanical damage.

Thermal insulation: fats conduct heat very poorly – subcutaneous fat stores help heat retention in endothermic animals. Incompressible blubber is an important insulator in diving mammals.

FATS and oils are typical triglycerides which differ chemically in the nature of their hydrocarbon chains – these chains may be **saturated** ($[-CH_2.CH_2-]_n$) or partially **unsaturated** (contain some –C=C– bonds).

FATS have a high proportion of **saturated hydrocarbon chains,** and are **solid** at ***room*** **temperature**, whereas oils have a high proportion of **unsaturated hydrocarbon chains**, and are **liquid at room temperature**.

Blocked sebaceous glands may cause pimples or blackheads!

Nutrition: both bile acids and vitamin D (involved in fat digestion and Ca^{2+} absorption respectively) are manufactured from steroids.

1.1O Lipids – Structure and Function

1. Draw the structure of a glycerol molecule, saturated fatty acid and unsaturated fatty acid. Explain how a double bond affects the shape of the fatty acid molecule.

2. Draw a diagram to show a condensation / hydrolysis reaction occurring between glycerol and fatty acids to form a triglyceride. Label the ester link and which parts are hydrophobic / hydrophilic.

3. Draw the structure of a phospholipid. What significance do these molecules have?

4. Discuss when it would be advantageous to have lipids as an energy store as opposed to carbohydrates.

5. Discuss when it would be advantageous to have carbohydrates as an energy store as opposed to lipids.

6. Which elements are always found in lipids? Which elements are sometimes found in lipids?

7. 'Lipids' is an umbrella term for oils, fats and waxes. How do the different types of lipid vary?

8. Discuss how the properties of lipids help them to carry out functions in living organisms. Include energy storage, insulation, protection, buoyancy and solubility.

9. Saturated fats have been linked to heart disease.
   - i. What exactly is meant by heart disease
   - ii. What is a saturated fat?
   - iii. What types of food contain high levels of saturated fat?
   - iv. Why is it difficult to prove conclusively that saturated fats contribute to heart disease?